DESCRIPTION

OPTICAL HEAD AND

OPTICAL DISC DRIVE INCLUDING THE OPTICAL HEAD

5   **TECHNICAL FIELD**

The present invention relates to an optical head for optically reading and/or writing data from/on an information storage medium such as an optical disc.

10   **BACKGROUND ART**

Recently, densities of optical discs have been further increased. For example, a phase change optical disc, on which preformed grooves have a pitch of 0.32 μm, information tracks also have a track pitch of 0.32 μm and a coating layer to

15   protect its information storage layer has a thickness of 0.1 mm, is known as a typical optical disc with an increased density. To read and/or write data from/on such an optical disc, the optical head of an optical disc drive may include a light source with a wavelength of 405 nm and an objective lens

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with a numerical aperture NA of 0.85, for example.

A high-density optical disc has such a narrow information track pitch that the optical head needs to perform a tracking control operation with very high precision. Accordingly, once a deviation has occurred in a tracking error signal due to the shift of the objective lens or the tilt of the optical disc, the tracking control operation can no longer be performed with the required precision, thus causing some problems. As used herein, the "deviation" of the tracking error signal refers to a gap (or distance) between the beam spot location and the center of the information track when the tracking error signal crosses the zero level.

Also, data is written on a phase change optical disc by changing the reflectance. The phase change optical disc has a narrow track pitch between adjacent information tracks. Accordingly, if the adjacent information tracks have mutually different reflectances, then the tracking error signal could not be detected accurately due to the difference. Furthermore, due to an error occurring during the

manufacturing process of optical discs, the information track

pitch might be variable from one location to another. In that

case, the tracking error signal could not be detected

accurately, either. Then, the tracking control operation

5   could not be carried out with sufficient precision on a high-

density optical disc. For that reason, efforts for detecting

the tracking error signal as accurately as possible have been

carried on.

For example, PCT International Application Publication

10 No. WO 97/15923 discloses a technique of reducing the

deviation that could occur in a tracking error signal due to

the shift of an objective lens and the tilt of an optical

disc. Hereinafter, a configuration for realizing the

technique disclosed in this document will be described.

15   FIG. 1(a) shows a configuration for a conventional

optical head 100. The optical head 100 includes: a light

source 101; a lens 102 for transforming the light emitted from

the light source 101 into luminous flux of parallel rays; half

mirrors 103 and 106 for reflecting a portion of incoming light

and transmitting another portion of the light; an objective lens **104** for focusing the light; a focus control section **107** for performing a focus control operation by detecting the luminous flux that has been reflected from an optical disc

5 **105**; and a light receiving section **108** for receiving the luminous flux, reflected from the optical disc **105**, at a plurality of light receiving areas.

The optical head **100** operates in the following manner. Specifically, the light emitted from the light source **101** is

10 focused on the optical disc **105** by way of the lens **102**, half mirror **103** and objective lens **104**. A portion of the luminous flux of reflected rays, which has been reflected from the optical disc **105**, is further reflected by the half mirror **106** toward the focus control section **107**. The rest of the

15 reflected luminous flux is transmitted through the half mirror **106** to enter the light receiving section **108**. The focus control section **107** detects a focus error signal based on the received signal and controls the distance between the objective lens **104** and the optical disc **105** with the detected

20 signal such that the light emitted from the light source **101**

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is focused on the optical disc **105** with a desired precision.

On the other hand, the signal received at the light receiving

section **108** is used to generate a tracking error signal. The

light is focused on an information track, which extends in the

5 direction coming out of the paper.

FIG. **1(b)** shows the cross section of the luminous flux

received at the light receiving section **108**. The cross

section **110** of the luminous flux is split into two by a

division line **109a**, which extends parallel to the information

10 tracks, and further split by two more division lines **109b** and

109c, which cross the division line **109a** at right angles. In

this manner, the cross section of the luminous flux is divided

into eight areas **108a** through **108h**. As the optical disc **105**

rotates, the beam spot of the reflected light apparently moves

15 from the area **108a** toward the area **108g**, for example. On the

other hand, the area **108i** is a light shielding area, which

cuts off the incident light. The light rays falling on these

areas **108a** through **108h** are detected as signals representing

their respective quantities of light. If the signals detected

20 by these areas **108a** through **108h** are identified by their

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reference numerals, the tracking error signal **TE** is given by:

$$TE = (108c + 108e - 108d - 108f) - k(108a + 108g - 108b - 108h) \quad (1)$$

where k is a correction factor. If the objective lens **104** is moved perpendicularly to the information tracks, then the

5   cross section **110** of the luminous flux shifts perpendicularly to the division line **109a** on the light receiving section **108**. As a result, an offset is produced in a so-called push-pull signal (108c + 108e − 108d − 108f). This offset is corrected with the signal (k(108a + 108g − 108b − 108h)). The correction

10   factor k is defined such that the offset of the tracking error signal decreases as the objective lens **104** moves.

It should be noted that the "deviation" and "offset" of the tracking error signal are two different notions. Specifically, the "deviation" of the tracking error signal

15   changes incessantly according to the positional relationship between the focal point of the light beam and the information storage layer and the reflectance of the information storage layer. Accordingly, the deviation cannot be minimized uniformly by using a factor such as the correction factor

described above.   On the other hand, the "offset" of the

tracking error signal is produced steadily in the overall

signal due to the shift of the objective lens described

above, for example, and can be reduced uniformly with the

5   correction factor.

FIG. 2 schematically shows the light intensity

distribution of the luminous flux 110 that has been reflected

from the tilted optical disc 105.   As used herein, "tilting"

means tilting a normal, which is defined perpendicularly to

10   the optical disc 105, parallel to the paper in FIG. 1(a).

When the optical disc 105 tilts, the light diffracts on the

information track, thus making the light intensity

distribution of the reflected light non-uniform.   In FIG. 2,

the hatched areas 110-1 represent the areas in which zero-

15   order and first-order components of the luminous flux

diffracted by the information track are superposed one upon

the other.   The remaining area 110-2 of the luminous flux 110,

other than the hatched areas 110-1, represents an area

receiving only the zero-order diffracted light, i.e., where no

20   diffracted light components are superposed.   As can be seen

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from FIG. 2, the hatched areas **110-1** are asymmetric with respect to the division line **109a**.

When the light intensity distribution is asymmetric, the light receiving section **108** cannot judge whether that state

5   was caused by the tilt of the optical disc **105** or by a bad tracking state. If a tracking error signal is generated from such reflected light, then the tracking error signal will represent the bad tracking state all the way and therefore have a low signal precision. For that reason, the light

10 shielding area **108i** is provided as shown in FIG. **1(b)** such that the portion of the light corresponding to the significantly asymmetric portion of the intensity distribution is not converted into a signal (i.e., not used to generate or detect a tracking error signal). In this manner, the

15 detection errors of the tracking error signal can be reduced.

There are some optical discs on which address information and other identification information is pre-recorded as wobbles of information tracks (i.e., by way of a wobble signal). FIG. 3 is a partial enlarged view of wobbled

20 information tracks **105-1** through **105-3** on the optical disc

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105. These information tracks 105-1 through 105-3 have respective wobbles representing the information recorded there. The wobbles of the three information tracks 105-1 through 105-3 change independently of each other. The technique of detecting such a wobble signal with a push-pull signal is disclosed in Japanese Laid-Open Publication No. 7-14172, for example.

The tracking error signal to be obtained from the light reflected from the high-density optical disc 105 will be described by reference to the results of numerical simulations. Those simulations were done with the conventional optical head 100 shown in FIG. 1 under the conditions that the light had a wavelength of 405 nm, the information tracks had a track pitch of 0.32 μm and a groove depth that was one-twelfth of the wavelength, the NA was 0.85, and the objective lens had a focal length of 2 mm. It should be noted that the information track groove is a recessed groove defined between two raised information tracks. The information tracks and information track grooves are defined herein as such. However, when viewed from over the other side of the optical

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disc **105**, the tracks and track grooves will be recessed and

raised, respectively. Thus, the following description will be

mainly focused on the "information tracks".

Hereinafter, it will be described how the tracking error

5 signal should be affected in respective situations where the

objective lens has shifted, where the optical disc is tilted,

where the pitch between the information tracks is variable,

and where adjacent information tracks have mutually different

reflectances.

10   (1) Offset of tracking error signal due to the shift of

objective lens:

FIG. **4** schematically shows the light intensity

distribution of a luminous flux that was reflected from the

high-density optical disc and detected by the light receiving

15 section. The hatched areas represent areas where the zero-

order and first-order components of the luminous flux,

diffracted by the information track grooves of the optical

disc **105**, were superposed one upon the other. The other non-

hatched area consisted essentially of the zero-order

20 diffracted light only (i.e., the area where no diffracted

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light components were superposed). Compared with the light intensity distribution shown in FIG. 1(b) or FIG. 2, the gap **L** between the two hatched areas is wider and the area consisting essentially of the zero-order diffracted light is broader in

5   the light intensity distribution shown in FIG. 4.   This is because the high-density optical disc has a narrower pitch between the information tracks.

In such a distribution, the push-pull signal has a low degree of modulation, and therefore, even if the objective

10 lens **104** has been shifted just slightly, a non-negligible offset will be produced in the signal.   Such a luminous flux is received at the respective divided areas shown in FIG. 4. The gap between the two division lines **109b** and **109c** is approximately equal to the maximum width of the diffracted

15 light superposed areas (i.e., the hatched areas shown in FIG. 4) as measured along the division line **109a**.   It should be noted that the light shielding area **108l** shown in FIG. 1(b) is not provided because the offset correction is the only concern here.

20   FIG. **5** shows a relationship between the shift of the

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objective lens **104** and the symmetry of the tracking error signal. The abscissa represents the shift of the objective lens while the ordinate represents the symmetry of the tracking error signal. The symmetry is obtained herein as the

5 ratio of the offset voltage to the voltage amplitude. It can be seen that while the shift of the objective lens falls within the range of ±0.3 mm, good symmetry is maintained and the offset is corrected sufficiently.

(2) Non-uniform information track pitch

10 If the pitch between information tracks is non-uniform, then some pair of adjacent information tracks at one location on the optical disc **105** may be relatively close to each other but another pair of adjacent information tracks at another location on the optical disc **105** may be relatively distant

15 from each other. FIG. **6** shows a model on which the leftmost one of three information tracks may be displaced. On this model, the waveform of the tracking error signal was simulated.

FIGs. **7(a)** and **7(b)** show the waveforms of the tracking

20 error signals obtained by displacing the leftmost information

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track. In this case, the information track was displaced by ± 20 nm. FIG. 7(a) shows the waveforms of push-pull signals with no offset corrected. In FIG. 7(a), the beam spot location (i.e., the focal point of the light beam) of zero is

5   the center of the reference information track and corresponds to the center of the central track shown in FIG. 6 (which will be referred to herein as the "center track"). In the range where the beam spot locations are negative, signals representing the leftmost information track to be displaced in

10 FIG. 6 appear. On the other hand, in the range where the beam spot locations are positive, signals representing the rightmost information track in FIG. 6 appear.

The three signal waveforms 114, 115 and 116 shown in FIG. 7(a) are signals obtained by displacing the leftmost

15 information track in three stages. More specifically, the waveform 115 is obtained by arranging the leftmost information track at the originally designed location; the waveform 114 is obtained by displacing the leftmost information track by 20 nm toward the center track; and the waveform 116 is obtained by

20 displacing the leftmost information track by 20 nm away from

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the center track. It should be noted that the rightmost track

is supposed to be arranged just as originally designed. In

FIG. 7(a), a significant offset variation is observed in the

vicinity of each information track displaced from the original

5   location (i.e., near the left-hand-side peak of the waveform),

which shows the effects of the non-uniform information track

pitch.

FIG. 7(b) shows the waveforms of tracking error signals

of which the offsets are corrected. The offsets are corrected

10 with an objective lens position signal. As in FIG. 7(a), the

three waveforms **117, 118** and **119** shown in FIG. 7(b) are

signals obtained by displacing the leftmost information track

in three stages. More specifically, the waveform **118** is

obtained by arranging the leftmost information track at the

15 originally designed location; the waveform **117** is obtained by

displacing the leftmost information track by 20 nm toward the

center track; and the waveform **119** is obtained by displacing

the leftmost information track by 20 nm away from the center

track. Compared with FIG. 7(a), the effects of the offset

20 variation on the signal waveforms are reduced significantly in

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FIG. **7(b)**. This means that the offset variation caused by the non-uniformity of information track pitches is corrected by the offset correcting means described above. It should be noted that the correction factor used in the calculations for FIG. **7(b)** has the same value as the correction factor for correcting the offset of the objective lens as described above.

(3) Tilt of the optical disc:

Next, it will be considered whether or not the deviation of the tracking error signal due to the tilt of the optical disc **105** can be reduced when the light shielding area **108i** (see FIG. **1(b)**) is provided for the light receiving section **108**. It should be noted that the "deviation" of the tracking error signal refers to the gap (or distance) between the beam spot location and the center of the information track when the tracking error signal crosses the zero level as described above.

FIG. **8** shows how the waveform of the tracking error signal changes when the width of the light shielding area **108i** is changed in the direction in which the division line **109a**

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(see FIG. **1(b)**) extends. The abscissa represents the beam spot location, which is defined with respect to the center of the information track as the origin, while the ordinate represents the signal level. The width of the light shielding

5   area **1081** was changed in three steps, thereby obtaining three waveforms **111**, **112** and **113**. Specifically, the waveform **111** was obtained when the width of the light shielding area **1081** was zero (i.e., when no light shielding area **1081** was provided), the waveform **112** was obtained when the width of the

10 light shielding area **1081** was 20% of the diameter of the luminous flux, and the waveform **113** was obtained when the width of the light shielding area **1081** was 35% of the diameter of the luminous flux. The coating layer of the optical disc **105** had a thickness of 100 μm and the disc had a tilt of 0.6

15 degrees.

As can be seen from FIG. **8**, at the zero beam spot location, the signal levels should have been equal to zero but the actual signal levels decreased below the zero level and the magnitudes of the deviations were in the order of the

20 waveforms **111**, **112** and **113**. That is to say, the greater the

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width of the light shielding area **1081**, the greater the deviation of the tracking error signal. Consequently, as for high-density optical discs to be developed and put on the market in the near future, the deviation of the tracking error signal cannot be reduced by the conventional technique.

(4) Offset produced in the tracking error signal on the boundary between information tracks with different reflectances:

FIG. **9** shows the cross sections of three information tracks. Among the tracks shown in FIG. **9**, the center track and another information track on the right-hand side are supposed to have a reflectance of 1 and be unrecorded tracks. On the other hand, the other hatched information track on the left-hand side is supposed to have a reflectance of **0.5** and be a recorded track. The optical disc **105** is supposed to have multiple sets of these tracks that are arranged periodically.

FIG. **10(a)** shows the waveforms of push-pull signals of which the offsets are not corrected. Among the three signal waveforms shown in FIG. **10(a)**, the bold curve represents the waveform of a push-pull signal at the focal point of the beam

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spot, the solid curve represents the waveform of a push-pull

signal when the focal point of the beam spot is shifted by

+0.2 μm, and the dashed curve represents the waveform of a

push-pull signal when the focal point of the beam spot is

5 shifted by -0.2 μm.   The focal point of the beam spot is

"shifted" perpendicularly to the optical disc 105, i.e., in

the direction in which the light beam is radiated toward the

optical disc 105.   In this case, the positive direction refers

to shifting the focal point toward the optical head as viewed

10 from the optical disc 105, while the negative direction refers

to shifting the focal point in the opposite direction.   In

these waveforms, a significant offset variation due to the

difference in reflectance between adjacent information tracks

and the change of that offset variation with the focus shift

15 of the beam spot are recognized.

Thus, the waveforms of offset-corrected tracking error

signals were calculated using the same correction factor as

that used to correct the offset resulting from the shift of

the objective lens.   FIG. 10(b) shows the waveforms of

20 tracking error signals of which the offsets are corrected.

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Among the three signal waveforms shown in FIG. 10(b), the bold curve represents the waveform of a push-pull signal at the focal point of the beam spot, the solid curve represents the waveform of a push-pull signal when the focal point of the

5   beam spot is shifted by +0.2 μm, and the dashed curve represents the waveform of a push-pull signal when the focal point of the beam spot is shifted by -0.2 μm. It can be seen that the offset variations of the three waveforms shown in FIG. 10(b) are much less remarkable than those shown in FIG.

10   10(a).

However, around the beam spot locations of 0 μm and +0.32 μm, the offset variation changes with the focal point of the beam spot and the three waveforms cross the zero level at mutually different locations. In addition, the magnitude

15   of change of the offset variation with the focal point of the beam spot is not constant among the three information tracks. Accordingly, even if the correction factor for the offset correction is changed, the deviation of the tracking error cannot always be reduced for every information track.

20   To sum up, the above-mentioned combination of conditions

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for a high-density optical disc has no effects of reducing the deviation of the tracking error signal resulting from the tilt of the optical disc as described for (3) and cannot correct sufficiently the offset variation produced in the tracking

5 error signal on the boundary between information tracks with different reflectances (or the offset variation caused by the focus shift of the beam spot, in particular) as described for (4).

Furthermore, in an optical disc with wobbled information 10 tracks (see FIG. 3), the gap between the central information track and its adjacent information track changes with this wobble. As already described with reference to FIGs. 7(a) and 7(b), the push-pull signal is easily affected by the adjacent information track. The wobble signal of one information track 15 may be represented by the distance from its adjacent information track. Accordingly, if the wobble signal is detected with the push-pull signal to be easily affected by the adjacent information track, then crosstalk will increase between the wobble signals of the two adjacent information 20 tracks.

DISCLOSURE OF INVENTION

An object of the present invention is to get a tracking control done exactly on the center of a target information track on an optical disc. Another object of the present invention is to detect a wobble signal from an optical disc, on which information is recorded as wobbles, while minimizing a crosstalk phenomenon to be caused between the wobble signals of two adjacent information tracks.

An optical head according to the present invention is used to read and/or write data from/on a storage medium having at least two tracks with mutually different reflectances. The optical head includes: a light source; an objective lens for focusing light, which has been emitted from the light source, onto one of the tracks of the storage medium; and light receiving means. The light receiving means includes a plurality of light receiving areas and a non-light-receiving area. The light receiving areas receive a first type of reflected rays, where zero-order and first-

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order components of the light diffracted by the track are superposed one upon the other, to generate a light quantity signal representing the quantity of light of the first type of reflected rays. The non-light-receiving area is provided

5 between the light receiving areas so as not to receive a second type of reflected ray consisting essentially of the zero-order components. As measured in a first direction in which the light receiving areas are arranged, a gap between the light receiving areas is longer than the width of the

10 non-light-receiving area. The optical head further includes tracking error signal generating means for generating a tracking error signal based on the light quantity signal.

As measured in a second direction perpendicular to the first direction, the length of the light receiving areas may

15 be smaller than the width of the first type of reflected rays.

As measured in the second direction, the overall length of the light receiving areas may be greater than a luminous flux of reflected rays.

20 If the light source radiates light with a wavelength λ,

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the objective lens has a numerical aperture NA and the track

has a period T, the optical head may read and/or write data

from/on a storage medium that satisfies the inequality $0.44 <$

$\lambda / (NA \cdot T) - 1$.

5   The optical head may further include light splitting

means for splitting a luminous flux of reflected rays into

the first and second types of reflected rays.

A drive according to the present invention makes an

optical head read and/or write data from/on a storage medium

10 having at least two tracks with mutually different

reflectances. The optical head includes: a light source; an

objective lens for focusing light, which has been emitted

from the light source, onto one of the tracks of the storage

medium; and light receiving means. The light receiving means

15 includes a plurality of light receiving areas and a non-

light-receiving area. The light receiving areas receive a

first type of reflected rays, where zero-order and first-

order components of the light diffracted by the track are

superposed one upon the other, to generate a light quantity

20 signal representing the quantity of light of the first type of

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reflected rays. The non-light-receiving area is provided between the light receiving areas so as not to receive a second type of reflected ray consisting essentially of the zero-order components. As measured in a first direction in which the light receiving areas are arranged, a gap between the light receiving areas is longer than the width of the non-light-receiving area. The optical head further includes tracking error signal generating means for generating a tracking error signal based on the light quantity signal and shifting means for changing the position of the lens parallel to the tracks responsive to a drive signal. The drive further includes: control signal generating means for generating a control signal that controls the position of the lens such that the light follows the tracks of the optical disc on the storage medium in response to the tracking error signal, and driving means for generating the drive signal that drives the shifting means in response to the control signal.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1(a) shows a configuration for a conventional

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optical head **100** and FIG. **1(b)** shows the cross section of a luminous flux received at the light receiving section **108** thereof.

FIG. **2** schematically shows the light intensity 5 distribution of a luminous flux **110** that has been reflected from a tilted optical disc **105**.

FIG. **3** is a partial enlarged view of wobbled information tracks **105-1** through **105-3** on the optical disc **105**.

FIG. **4** schematically shows the light intensity 10 distribution of a luminous flux that has been reflected from a high-density optical disc.

FIG. **5** is a graph showing a relationship between the shift of an objective lens **104** and the symmetry of a tracking error signal.

15 FIG. **6** shows a model on which the leftmost one of three information tracks may be displaced.

FIGs. **7(a)** and **7(b)** show the waveforms of tracking error signals obtained by displacing the leftmost information track.

FIG. **8** is a graph showing how the waveform of a tracking 20 error signal changes when the width of an light shielding area

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1081 is changed in the direction in which the division line **109a** (see FIG. **1(b)**) extends.

FIG. **9** is a cross-sectional view of three information tracks.

5   FIG. **10(a)** is a graph showing the waveforms of push-pull signals of which the offsets are not corrected.

FIG. **10(b)** is a graph showing the waveforms of tracking error signals of which the offsets are corrected.

FIG. **11** is a block diagram of an optical disc drive **200** according to the present invention.

FIG. **12** shows a configuration for an optical head **220** according to a first embodiment.

FIG. **13** shows how an incoming luminous flux is split to multiple areas.

15   FIG. **14** is a graph showing the waveforms of TE signals when the optical disc has a tilt of 0.6 degrees.

FIG. **15** is a graph showing how the waveforms of TE signals change when only the information track pitch is changed.

20   FIG. **16** shows a diffraction element **19** according to a

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third embodiment.

FIG. **17** is a graph showing the waveforms of TE signals obtained from information tracks with different reflectances.

FIG. **18** shows a diffraction element **22** according to a

5 fourth embodiment.

FIG. **19** is a graph showing the waveforms of a TE signal obtained by using the diffraction grating **22** of the fourth embodiment.

FIG. **20** shows a configuration for an optical head **230**

10 according to a fifth embodiment.

FIG. **21** shows a configuration for an optical head according to a sixth embodiment.

BEST MODE FOR CARRYING OUT THE INVENTION

15 Hereinafter, preferred embodiments of an optical disc drive and an optical head according to the present invention will be described with reference to the accompanying drawings.

EMBODIMENT 1

20 FIG. **11** shows how functional blocks of an optical disc

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drive 200 according to a first embodiment of the present invention may be arranged. The optical disc drive 200 includes an optical head 220, a control signal generating section 211, a driver circuit 212 and a read processing

5   section 213. The optical disc drive 200 can read and/or write data from/on a given optical disc.

The optical head 220 is an optical system for emitting a light beam toward the optical disc 105 and receiving the light that has been reflected from the optical disc 105. The

10 optical head 220 reads and/or writes data from/on the optical disc 105. Furthermore, the optical head 220 includes a signal processor for generating a tracking error signal (which will be referred to herein as a "TE signal"), a focus error (FE) signal, a read signal and other signals. The detailed

15 configuration of the optical head 220 will be described later. The optical disc 105 is shown in FIG. 11 just for convenience sake. Thus, it should be noted that the optical disc 105 is not an integral part of the optical disc drive 200. The optical disc 105 is supposed to be loaded into the optical

20 disc drive 200.

In response to the TE signal supplied from the optical head **220**, for example, the control signal generating section **211** generates a control signal for controlling the radial positional relationship between the light beam spot and the information track of the optical disc **105**. The control signal generated by the control signal generating section **211** is output to the driver circuit **212**. In response to the control signal received, the driver circuit **212** generates a drive signal and then supplies it to a tracking actuator or the transport stage (not shown) of the optical head **220**. Each of the tracking actuator and transport stage moves either an objective lens **204** only or the optical head **220** in its entirety in the radial direction of the optical disc **105**, thereby controlling the radial positional relationship between the light beam spot and the information track of the optical disc **105**. While a servo control operation such as a focus control or a tracking control is being carried out with good stability, the read processing section **213** performs a predetermined read process on the light that has been reflected from the optical disc **105**, thereby reading the data

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from the optical disc **105**.

Next, the configuration of the optical head **220** will be described. FIG. **12** shows a configuration for an optical head **220** according to this embodiment. The optical head **220** includes a light source **201**, a beam splitter **202**, a collimator lens **203**, the objective lens **204**, a diffraction element **206**, a light receiving section **207**, a position signal detecting section **208**, a TE signal generating section **209** and an offset correcting section **210**.

The light source **201** may emit a violet laser beam with a wavelength of 405 nm, for example. The beam splitter **202** transmits a portion of the laser beam and reflects the rest of the light. The collimator lens **203** transforms the light coming from the light source **201** into a luminous flux of rays. The objective lens **204** converges the light beam coming from the light source **201**, thereby forming a focal point at a predetermined distance from the objective lens **204**. The diffraction element **206** receives the luminous flux that has been reflected from the optical disc **105** and then selectively passes a portion of the luminous flux through one or more

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predetermined diffraction regions or cuts off the rest of the luminous flux with one or more opaque regions. To selectively pass or cut off a given luminous flux in this manner will be referred to herein as "splitting" the luminous

5 flux. The light receiving section **207** includes a plurality of light receiving areas, each of which generates a light quantity signal representing the quantity of light received there. The position signal detecting section **208** detects the positions of the light receiving section **207** and objective

10 lens. The offset correcting section **210** corrects the offset to be produced in the TE signal in cooperation with the TE signal generating section **209**.

Hereinafter, it will be described, along the optical path of the light, exactly how this optical head **220** carries

15 out its processing. The light radiated from the light source **201** is transmitted through the beam splitter **202**, transformed into a luminous flux of parallel rays by the collimator lens **203**, incident onto the objective lens **204**, and then focused by the objective lens **204** onto the information storage layer

20 of the optical disc **105**.

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Thereafter, the light is reflected from the optical disc 105, passed through the objective lens 204 and collimator lens 203 again, incident onto the beam splitter 202 and then reflected by the beam splitter 202 toward the diffraction

5   element 206, where the luminous flux of reflected rays is split into multiple light rays through diffraction. The light receiving section 207 includes a plurality of light receiving areas to receive the respective light rays that have been produced by the splitting action of the diffraction element

10   206. That is to say, those light rays, obtained by getting the luminous flux split by the diffraction element 206, are guided to their associated light receiving areas provided on the light receiving section 207. In response, the respective light receiving areas generate signals representing the

15   quantities of light received there.

From some of the light receiving areas of the light receiving section 207, a signal for generating the TE signal is output to the TE signal generating section 209. On the other hand, from another light receiving area of the light

20   receiving section 207, a signal for detecting the position

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signal of the objective lens **204** is output to the position

signal detecting section **208**. In response to the signal

supplied from the light receiving section **207**, the TE signal

generating section **209** generates the TE signal and outputs it

5 to the offset correcting section **210**. In accordance with the

signal supplied from the light receiving section **207**, the

position signal detecting section **208** detects the position

signal of the objective lens **204** and then passes it to the

offset correcting section **210**.

10   The offset correcting section **210** sets the correction

factor so as to decrease the offset of the TE signal and

performs predetermined computation processing, thereby

generating an offset-corrected TE signal. It should be noted

that an offset is produced in the TE signal by changing the

15 position of the objective lens **204**. By using this offset-

corrected TE signal, the control signal generating section **211**

shown in FIG. **11** generates a control signal and performs the

tracking control just as intended. It should be noted that

the optical head actually needs some other normal components,

20 including a focus detecting section and a driving section to

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change the position of the objective lens. However, since all of those additional components may be known ones, the description thereof will be omitted herein.

Hereinafter, it will be described in detail how the incoming luminous flux is split by the diffraction element 206. FIG. 13 shows how the incoming luminous flux is split to multiple areas. The four areas 6a, 6b, 6e and 6f are areas through which light rays for detecting the objective lens position signal pass, while the two areas 6c and 6d are areas through which light rays for detecting the TE signal pass. The division lines 11a through 11e split the incoming luminous flux. Specifically, the division line 11a splits the luminous flux into two along the information tracks. The division lines 11b and 11c are borders defining the objective lens position signal detecting areas and split the luminous flux perpendicularly to the information tracks. The division lines 11d and 11e are borders defining the TE signal detecting area and also split the luminous flux perpendicularly to the information tracks.

Furthermore, the area Rac between the areas 6a and 6c,

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the area **Rbd** between the areas **6b** and **6d**, the area **Rce** between

the areas **6c** and **6e**, and the area **Rdf** between the areas **6d** and

6f are opaque areas that are designed so as not to guide the

incoming light to the light receiving section **207**. These

5   areas are provided so as to prevent the light entering these

areas from being used to detect the TE signal or objective

lens position signal. To achieve such an object, however, the

optical head **220** may adopt a different configuration. For

example, a diffraction grating may be provided in these areas

10   to prevent the light from being guided to the light receiving

areas of the light receiving section **207**. Alternatively, no

features may be provided for these areas but instead the light

receiving areas may be selectively removed from the light

receiving section **207** on which the light rays, having passed

15   through these areas, will be incident.

     FIG. **13** illustrates the beam spot shape **12** of the

luminous flux that has entered this diffraction element **206**.

The hatched areas **12-1** represent the areas in which the zero-

order and first-order components of the diffracted light

20   coming from the information track are superposed one upon the

<div align="center">35</div>

other. The remaining area 12-2 of the beam spot 12, other than those hatched, represents an area where only the zero-order component of the diffracted light is incident.

For example, if a signal that has passed through the area

5   6c of the diffraction element 206 shown in FIG. 13 and then detected at its associated light receiving area of the light receiving section 207 is identified by "6c", then the corrected TE signal is given by

$$TE = (6c - 6d) - k(6a + 6e - 6b - 6f) \tag{2}$$

10 where k is the offset correction factor. The first term of Equation (2) is the uncorrected TE signal (i.e., push-pull signal) and the second term multiplied by k is the objective lens position signal. These are just as already described for the prior art.

15   One of the principal features of the optical head 220 of this embodiment is that in the direction parallel to the information tracks (i.e., along the division line 11a), the gap between the division lines 11d and 11e is set shorter than the maximum length of the areas (i.e., the hatched areas 12-1

20 shown in FIG. 13) in which the zero-order and first-order

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components of the diffracted light coming from the information

track are superposed one upon the other. The optical head **220**

is also characterized in that the overall length of the

diffraction element **206** as measured perpendicularly to the

5   information tracks (i.e., along the division lines **11b** and

11d) is equal to or greater than the diameter of the beam spot

12. Thus, the deviation of the TE signal, caused by the tilt

of the optical disc **105**, can be reduced. In this case, the

tilt of the optical disc **105** means a tilt to be produced by

10   rotating the plane of the optical disc **105** on the tangential

line of the information tracks, i.e., a radial tilt.

Next, the TE signal to be obtained by this configuration

will be described. FIG. **14** shows the waveforms of TE signals

when the optical disc has a tilt of 0.6 degrees. The

15   abscissa represents the beam spot location, which is defined

with respect to the center of the information track as the

origin, while the ordinate represents the signal level. The

numerical calculations were carried out under the combination

of conditions that adjacent information track grooves had a

20   pitch of 0.32 μm, the light had a wavelength of 405 nm, the

objective lens had an numerical aperture of 0.85 and the

coating layer had a thickness of 100 nm. Also, supposing the

gap between the division lines **11b** and **11c** is identified by V1,

the gap between the division lines **11d** and **11e** is identified

5   by V2, and these values V1 and V2 are represented as ratios to

the diameter of the beam spot **12**, V1 was assumed to be

constant at 0.65.

FIG. **14** shows the TE signals obtained by changing the gap

V2 between the division lines **11d** and **11e**. Specifically, the

10   waveform **13** represents a situation where $V2 = V1 = 0.65$, the

waveform **14** represents a situation where $V2 = 0.43$, and the

waveform **15** represents a situation where $V2 = 0.25$. The zero-

crossing points of the waveforms **13**, **14** and **15** are located on

the negative side (i.e., on the left-hand side of the origin),

15   right on the origin, and on the positive side (i.e., on the

right-hand side of the origin), respectively. Accordingly,

under these conditions, by setting V2 equal to 0.43, the

deviation of the TE signal resulting from the tilt of the

optical disc **105** (i.e., the gap between the zero-crossing

20   point of the waveform of the TE signal and the center of the

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information track) can be substantially eliminated. Also, if the pitch between adjacent information track grooves and the numerical aperture change, then the best V2 value changes, too. For that reason, V2 is preferably modified according to the

5   conditions. However, the conditions to which this embodiment is applicable are limited to the range to be described below.

Hereinafter, the range to which this embodiment is applicable will be described. As can be seen from FIG. **14**, unless this embodiment is applied with V1 set equal to V2, the

10 zero-crossing point of the TE signal shifts to the left-hand side of the origin (as indicated by the waveform **13** in FIG. **14**). However, if this embodiment is applied with V2 decreased, then the zero-crossing point shifts rightward (as indicated by the waveforms **14** and **15** in FIG. **14**). In other words, unless

15 the direction in which the zero-crossing point shifts due to the tilt of the optical disc **105** when this embodiment is not applied is opposite to the direction in which the zero-crossing point shifts with V2 decreased by applying this embodiment, the tracking error cannot be reduced.

20   FIG. **15** shows how the waveforms of TE signals change when

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V1 is set equal to V2 and when only the information track pitch is changed. Specifically, the waveform **16** is associated with an information track pitch of 0.35 μm, the waveform **17** is associated with an information track pitch of 0.33 μm, and the waveform **18** is associated with an information track pitch of 0.3 μm. The abscissa and ordinate of this graph represent the same quantities as the counterparts of FIG. **14** do. Due to the tilt of the optical disc **105**, the zero-crossing points of the waveforms shift in the negative direction as the information track pitch decreases. In the calculations shown in FIGs. **14** and **15**, the optical disc **105** is supposed to be tilted in the same direction. Thus, it can be understood that the tracking error can be reduced by decreasing V2 only when the zero-crossing point of the waveform is located on the negative range (i.e., only when the information track pitch is smaller than 0.33 μm).

Next, this restriction condition is generalized. The shift of the zero-crossing point of the TE signal due to the tilt of the optical disc **105** is caused by a coma aberration to be produced when the light passes through the coating layer

40

(not shown) of the tilted optical disc **105**. Also, this shift

results from a variation in intensity distribution in the

areas where the zero-order and first-order components of the

diffracted light coming from the information track are

5   superposed one upon the other. This variation in intensity

distribution is determined by how those components are

superposed at the edges of the luminous flux with a wave

aberration. Accordingly, the shift of the zero-crossing point

depends on the wavelength, information track pitch, and

10 numerical aperture of the objective lens. Supposing the

wavelength is denoted by λ, the information track pitch is T

and the numerical aperture of the objective lens is NA, a

quantity U is defined by

$$U = \lambda / (T \cdot NA) - 1 \qquad\qquad (3)$$

15 This quantity U represents the ratio of the gap W between the

right and left hatched areas shown in FIG. 13 to the diameter

of the luminous flux. If the boundary conditions of the

present invention and the prior art, i.e., $T = 0.33 \ \mu m$, $NA =$

0.85 and $\lambda = 405$ nm, are substituted into Equation (3), then U

20 is 0.44. Equation (3) shows that as T is decreased, U

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increases. Also, according to the conditions described above, this embodiment is applicable only when adjacent information track grooves have a pitch smaller than 0.33 μ m. Thus, the generalized application condition is

5      $U > 0.44$ (4)

It should be noted that if U is smaller than 0.44, then it is the application range of the prior art described above.

As described above, according to this embodiment, by detecting the TE signal from a range that is narrower than

10 the width of the areas, where the zero-order and first-order components of the diffracted light coming from the information track are superposed one upon the other, as measured along the information track, the tracking error due to the tilt of the optical disc can be reduced.

15 In the embodiment described above, the position signal detecting section **208** is provided. However, in an optical disc drive in which the shift of the objective lens can be sufficiently reduced to ± 0.05 mm or less, for example, the same effects are also achieved even if the position signal

20 detecting section **208** is omitted from the drive.

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EMBODIMENT 2

As a second embodiment of the present invention, an optical disc satisfying the inequality

5
$$0.40 < \lambda/(T \cdot NA) - 1 < 0.46 \tag{5}$$

where λ is the wavelength of light, NA is the numerical aperture of an optical head for reading and/or writing data from/on the optical disc and T is the period of information track grooves, will be considered.

10   In reading and/or writing data from/on such an optical disc, the optical head operates just as already described for the first embodiment, and the description thereof will be omitted herein. Instead, it will be described here why such an optical disc can minimize the deviation of the TE signal

15   due to its own tilt.

If the boundary condition (inequality (4)) as described for the first embodiment is modified into

$$U = 0.44 \tag{6}$$

then this is the condition on which the waveform **17** shown in

20   FIG. **15** was calculated.   As described above, in that case,

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almost no deviation is caused in the TE signal due to the tilt

of the optical disc **105** even by the conventional TE signal

generating method. Accordingly, an optical disc **105**

substantially satisfying $U = 0.44$ is preferably made. For

5 example, supposing the wavelength is 405 nm and NA is 0.85, an

optical disc, of which the information track pitch is defined

somewhere between 0.326 μ m and 0.340 μ m, can satisfy this

condition.

The waveform **13** shown in FIG. **14** represents a situation

10 where the information track pitch **T** is 0.32 μ m. On the other

hand, the waveform **16** shown in FIG. **15** represents a situation

where the information track pitch **T** is 0.35 μ m. The tilt of

the optical disc is supposed to be 0.6 degrees in both cases.

The deviations of the TE signal as represented by these

15 waveforms are far from being sufficiently small and are

preferably cut down to half or less. If $T = 0.32$ μ m, U is

0.49. On the other hand, if $T = 0.35$ μ m, U is 0.36. Thus,

the conditions represented by inequality (5) were obtained by

adopting intermediate values between the best U value of 0.44

20 represented by Equation (6) and these two U values. Those

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conditions substantially satisfy Equation (6).

As described above, even if the optical disc of this embodiment has a tilt of about 0.6 degrees, which is allowed for a normal optical disc, the optical disc can still reduce

5   the deviation of the TE signal due to that tilt to a substantially negligible level.

EMBODIMENT 3

An optical head according to a third embodiment of the

10 present invention is different from the optical head of the first embodiment only in the method of splitting the luminous flux by the light splitting means (i.e., diffraction element). Thus, the following description will be focused on this difference.

15   FIG. 16 shows a diffraction element 19 according to this third embodiment.   An optical head according to this embodiment can be obtained by substituting this diffraction element 19 for the diffraction element 206 shown in FIG. 12. The diffraction element 19 splits the luminous flux by areas

20 19a through 19g, which are defined by division lines 20a, 20b

45

and **20c**. FIG. **16** shows the beam spot shape **21** of the luminous

flux that has entered this diffraction element **19**.

The respective areas for the split luminous flux will be

further described. The four areas **19a, 19b, 19e** and **19f** are

5   areas through which light rays for detecting the objective

lens position signal pass. The two areas **19c** and **19d** pass the

light rays for detecting the TE signal. The area **19g** with

horizontal hatching may be a diffraction element for

diffracting the light ray and is designed such that even the

10   reflected light ray that has entered this area **19g** will not

reach an area of the light receiving section **207** for

generating the TE signal. The areas with oblique hatching

represent the areas where the zero-order and first-order

components of the diffracted light coming from the information

15   track are superposed one upon the other.

Hereinafter, the relationship between the widths **W1** and

W2 of the areas shown in FIG. **16** will be described. More

specifically, the width **W1** represents the gap between the

areas where the two types of components of the diffracted

20   light coming from the information track are superposed one

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upon the other. On the other hand, the width **W2** corresponds

to the width of the area where no TE signal should be detected.

The light rays that have been split to the respective

detecting areas **19a** through **19f** are then guided to, and

5   received at, the light receiving section **207**. For example, if

a signal that has passed through any area of the diffraction

element **19** shown in FIG. **16** and then detected at its

associated light receiving area of the light receiving section

207 is identified by the reference numeral given to that area

10   of the diffraction element **19**, then the corrected TE signal is

given by

$$TE = (19c - 19d) - k(19a + 19e - 19b - 19f) \qquad (7)$$

where k is the offset correction factor.

The first term of Equation (7) is the uncorrected TE

15   signal (i.e., push-pull signal) and the second term,

multiplied by the offset correction factor k, is the objective

lens position signal.

One of the features of this embodiment is to provide the

TE signal non-detecting area **19g** approximately at the center

20   of the incoming luminous flux and between the two areas where

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the zero-order and first-order components of the diffracted light coming from the information track are superposed one upon the other. Thus, the offset to be produced in the TE signal when adjacent information tracks have mutually

5   different reflectances can be reduced.

Hereinafter, the features of this embodiment will be described in further detail. FIG. 17 shows the waveforms of TE signals obtained from multiple information tracks with different reflectances. In this case, the ratio of the width

10   W2 of the TE signal non-detecting area 19g to the diameter of the luminous flux 20 is supposed to be 0.36. The other calculation conditions are identical with those already described with reference to FIG. 10. The information tracks with different reflectances are shown in FIG. 9, for example.

15   Among the three waveforms shown in FIG. 17, the bold curve represents a signal waveform at the focal point of the beam spot, the solid curve represents a waveform when the focal point of the beam spot is shifted by +0.2 μm, and the dashed curve represents a waveform when the focal point of the

20   beam spot is shifted by -0.2 μm. Compared with the waveforms

shown in FIG. 10(b), the respective waveforms shown in FIG. 17

have much closer zero-crossing points in the vicinity of the

respective centers of the information tracks (i.e., at the

location of 0 μm and the locations of $\pm$0.32 μm on the axis

5   of abscissas). Thus, the deviation of the TE signal has been

significantly reduced with respect to any focus shifting.

Next, it will be described why the deviation of the TE

signal could be reduced. If a beam spot crosses multiple

information tracks with various reflectances, then a

10 diffraction pattern, representing not only the periodicity of

any information track but also the periodicity of that

reflectance variation, will appear in the cross section of the

luminous flux reflected from the optical disc. Supposing one

of the three information tracks has a lower reflectance as

15 shown in FIG. 9, the period of the fundamental wave

representing the reflectance variation will be three times as

long as the information track pitch and the second- and third-

order components of the Fourier series will be 1.5 times as

long as, and 1.0 time as long as, the information track pitch,

20 respectively. Diffracted light that has come from a structure

with a period greater than the information track pitch has a small diffraction angle. In that case, the diffracted light will appear at the center of the luminous flux, too. However, by using the diffraction element **19** of this embodiment, the TE

5 signal is generated with the center portion of the luminous flux filtered out through the area **19g**. Accordingly, even if the intensity distribution has varied in that center portion, its effect is much smaller than the situation where the TE signal is generated with that center portion of the luminous

10 flux used. Consequently, the deviation of the TE signal can be reduced without varying the offset of the TE signal.

It should be noted that the widths **W1** and **W2** of the areas shown in FIG. **16** preferably satisfy the inequality $W1 > W2$. This is because if $W1 \leqq W2$, then the light rays represented by

15 the oblique hatching in FIG. **16** would overlap with the TE signal non-detecting area **19g**. In that case, if the TE signal were detected based on the variation in intensity distribution of those hatched areas, then the resultant accuracy would decrease. Particularly if the diffraction element **19** is fixed

20 to the optical head, the luminous flux shifts as the objective

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lens **204** is moved. As a result, the light rays in the hatched

areas further expand toward the TE signal non-detecting area

19g, thus making the TE signal even less accurate.

According to the embodiment described above, by providing

5   the TE signal non-detecting area at the center of the luminous

flux, the offset to be produced in the TE signal on the

boundary between multiple information tracks with mutually

different reflectances can be reduced.

10   EMBODIMENT 4

An optical head according to a fourth embodiment of the

present invention is different from the optical head of the

first embodiment only in the method of splitting the luminous

flux by the light splitting means (i.e., diffraction

15   element). Thus, the following description will be focused on

this difference.

FIG. **18** shows a diffraction element **22** according to this

fourth embodiment. An optical head according to this

embodiment can be obtained by substituting this diffraction

20   element **22** for the diffraction element **206** shown in FIG. **12**.

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The diffraction element 22 splits the respective light rays to areas 22a through 22g, which are defined by division lines 23a through 23e.   FIG. 18 shows the beam spot shape 24 of the luminous flux that has entered this diffraction element 19.

5   The respective areas for the split luminous flux will be further described.   The four areas 22a, 22b, 22e and 22f pass through the light rays which are used for detecting the objective lens position signal.   The two areas 22c and 22d pass the light rays for detecting the TE signal.   The area 22g

10   with horizontal hatching may be a diffraction element for diffracting the light ray and is designed such that even the reflected light ray that has entered this area 22g will not reach an area of the light receiving section 207 for generating the TE signal.

15   Furthermore, the area between the areas 22a and 22c, the area between the areas 22b and 22d, the area between the areas 22c and 22e, and the area between the areas 22d and 22f are opaque areas that are designed so as not to guide the incoming light to the light receiving section 207.   These areas are

20   provided so as to prevent the light entering these areas from

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being used to detect the TE signal or objective lens position

signal. As long as this object is achieved, the diffraction

element **22** may adopt a different configuration. For example,

a diffraction grating may be provided in these areas to

5   prevent the light from being guided to the light receiving

areas of the light receiving section **207**. Alternatively, no

features may be provided for these areas but instead the light

receiving areas may be selectively removed from the light

receiving section **207** on which the light rays, having passed

10   through these areas, will be incident.

Also, in FIG. **18**, the areas with oblique hatching

represent the areas where the zero-order and first-order

components of the diffracted light coming from the

information track are superposed one upon the other.

15   Furthermore, in FIG. **18**, W1 represents the gap between the

areas where the two types of components of the diffracted

light coming from the information track are superposed one

upon the other. On the other hand, W2 represents the width

of the TE signal non-detecting area **22g**. The light rays that

20   have been split to the respective detecting areas **22a** through

22f are then guided to, and received at, the light receiving section **207**. For example, if a signal that has passed through any area of the diffraction element **22** shown in FIG. **18** and then detected at its associated light receiving area

5 of the light receiving section **207** is identified by the reference numeral given to that area of the diffraction element **22**, then the corrected TE signal is given by

$$TE = (22c - 22d) - k(22a + 22e - 22b - 22f) \qquad (8)$$

where k is the offset correction factor.

10 The first term of Equation (8) is the uncorrected TE signal (i.e., push-pull signal) and the second term, multiplied by the offset correction factor k, is the objective lens position signal.

One of the features of this embodiment is to set the width of the TE signal generating areas **22c** and **22d** along the

15 information tracks (i.e., as measured along the division line **23a**) shorter than that of the obliquely hatched areas in the same direction and to provide the TE signal non-detecting area **22g** approximately at the center of the incoming luminous flux.

20 Thus, both the deviation of the TE signal due to the tilt of

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the optical disc and the offset to be produced in the TE

signal on the boundary between information tracks with

mutually different reflectances can be reduced at the same

time.   This is because the diffraction element **22** of this

5   embodiment includes not only areas corresponding to the areas

Rac, Rbd, Rce and **Rdf** of the diffraction grating **206** of the

first embodiment but also an area **22g** corresponding to the TE

signal non-detecting area **19g** of the diffraction element **19** of

the third embodiment.   Hereinafter, it will be described how

10   these two effects are achieved at the same time even if those

two configurations are combined.

First, the effect of reducing the deviation of the TE

signal due to the tilt of the optical disc is determined by

the ratio of the width of the TE signal detecting areas to

15   that of the obliquely hatched areas shown in FIG. **18.**

Accordingly, even if the area **22g**, not including the obliquely

hatched areas, is provided, that effect can be clearly

maintained.   Next, it will be considered how the TE signal

changes when the width of the areas **22c** and **22d** is decreased

20   along the division line **23a** and if the area **22g** is further

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provided. FIG. **19** shows the waveforms of TE signals obtained

by using the diffraction grating **22** of this embodiment. The

calculations were done under the same conditions as FIG. **17**

except that the ratio of the gap between the division lines

5   **23d** and **23e** to the diameter of the luminous flux and the ratio

of the width **W2** to the diameter of the luminous flux were both

0.36.   These waveforms exhibit good characteristics in which

the zero-crossing points hardly shifted due to the focus

shifting in the vicinity of the respective centers of

10 information tracks.   That is to say, even if the areas

corresponding to the areas **Rac, Rbd, Rce** and **Rdf** of the

diffraction grating **206** of the first embodiment and the area

22g corresponding to the TE signal non-detecting area **19g** of

the diffraction grating **19** of the third embodiment are

15 provided in combination, the effects of the respective

diffraction gratings of these two embodiments can be achieved

at the same time.

Thus, according to this embodiment, the deviation of the

TE signal due to the tilt of the optical disc **105** and the

20 offset to be produced in the TE signal on the boundary between

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the information tracks with different reflectances can be both

reduced.

EMBODIMENT 5

5   FIG. **20** shows a configuration for an optical head **230**

according to a fifth embodiment of the present invention.   The

optical head **230** includes the light source **201**, a polarization

beam splitter **225**, the collimator lens **203**, a polarizing

diffraction element **226**, a quarter-wave plate **227**, the

10   objective lens **204**, a holder **228**, the TE signal generating

section **209**, the offset correcting section **210** and a

distribution variation detecting section **229**.   In the optical

head **230** of this embodiment, any component having the same

function as the counterpart of the optical head **220** of the

15   first embodiment is identified by the same reference numeral

and the description thereof will be omitted herein.

        The polarizing diffraction element **226** is a diffraction

element, of which the diffraction efficiency changes with the

polarization direction, and functions as the light splitting

20   means.   The holder **228** holds the polarizing diffraction

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element 226, quarter-wave plate 27 and objective lens 4

together. The distribution variation detecting section 229

detects a variation in the light intensity distribution of the

luminous flux that has been reflected from the optical disc

5   105.

The light radiated from the light source 201 is incident

as a P-polarized light ray onto the polarization beam

splitter 225 and transmitted through the splitter 225. Next,

the light is transformed by the collimator lens 203 into a

10 luminous flux of parallel rays, which is incident onto, and

transmitted as it is through, the polarizing diffraction

element 226 so as to enter the quarter-wave plate 227.

Thereafter, the light that has passed through the quarter-

wave plate 227 is transformed into a circularly polarized

15 light ray, which is incident on, and focused on the

information storage layer of the optical disc 105 by, the

objective lens 204.

The light that has been reflected from the optical disc

105 passes through the objective lens 204 again and enters

20 the quarter-wave plate 227. After having passed through the

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quarter-wave plate **227**, the light is transformed into linearly polarized light, of which the polarization direction is perpendicular to that of the P-polarized accessing light and which enters the polarizing diffraction element **226** next.

5 The light that has entered the polarizing diffraction element **226** is diffracted this time almost entirely because its polarization direction is perpendicular to that of the accessing polarized light. The light is split by the polarizing diffraction element **226** into multiple light rays,

10 which are then incident onto the polarization beam splitter **225** by way of the collimator lens **203**. These polarized light rays are S-polarized, and therefore, are all reflected toward the light receiving section **207**.

The light rays, which have been produced by getting the

15 polarized light split by the polarizing diffraction element **226**, are detected at the light receiving section **207** and then supplied as signal for generating a TE signal to the TE signal generating section **209**. On the other hand, another signal, which has been divided by the polarizing diffraction

20 element **226** and detected at the light receiving section **207**

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so as to be used for detecting a light intensity distribution variation signal, is supplied to the light intensity distribution variation signal detecting section **229**.

The two signals, detected by these TE signal generating section **209** and distribution variation signal detecting section **229**, are both supplied to the offset correcting section **210**. The offset correcting section **210** defines the correction factor so as to reduce the offset to be produced in the TE signal due to a variation in the light intensity distribution of the detected luminous flux (i.e., the luminous flux that has been reflected from the optical disc and incident on the polarizing diffraction element **226**). By performing predetermined computation processing, the offset correcting section **210** generates an offset-corrected TE signal. By using this offset-corrected TE signal, a tracking control operation is carried out. The polarizing diffraction element **226** may split the luminous flux by the same method as the diffraction element **206** shown in FIG. **13**. For example, referring to FIG. **13**, the four areas **6a, 6b, 6e** and **6f** may be used as areas to pass the light rays for detecting a variation

in the light intensity distribution of the luminous flux, while the two areas **6c** and **6d** may be used as areas to pass the light rays for detecting the TE signal.

In this embodiment, the objective lens **4** and the polarizing diffraction element **226** functioning as the light splitting means are held together by the holder **228**. Accordingly, even during the tracking control operation, these members **204** and **226** are arranged so as to move together. In this arrangement, even if the objective lens **204** has shifted, the location of the detected luminous flux never changes with respect to the polarizing diffraction element **226**. Thus, by using the light rays that have passed through the areas **6a** through **6f**, the variation in information track pitch and the variation in the light intensity distribution of the detected luminous flux on the boundary between information tracks with different reflectances can be detected. Accordingly, the offset correction factor can be defined so as to correct the variation in information track pitch and the variation in offset on the boundary between information tracks with different reflectances without taking

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the offset of the TE signal due to the shift of the objective

lens into account. Consequently, the tracking error caused by

these factors can be further reduced.

Also, if the polarizing diffraction element **226** splits

5   the reflected light as shown in FIG. **16**, the location of the

detected luminous flux never moves, and the width **W2** of the TE

signal non-detecting area **19g** can be substantially equalized

with the width **W1** shown in FIG. **16**.   Then, more factors

causing the offset variation due to the focus shifting on the

10 boundary between information tracks with different

reflectances can be eliminated and the resultant offset in the

TE signal can be further reduced.

Thus, according to the embodiment described above, by

arranging the light splitting means to move together with the

15 objective lens and by making the light splitting means split

the light just like the counterpart of the third or fourth

embodiment described above, the offset correction factor can

be defined with a higher priority given to reducing the

variation in information track pitch and the offset variation

20 to be produced in the TE signal when adjacent information

tracks have mutually different reflectances. Consequently, the resultant offset of the TE signal can be further reduced.

EMBODIMENT 6

5   FIG. 21 shows a configuration for an optical head according to a sixth embodiment of the present invention. The optical head of this embodiment is obtained by adding a wobble signal detecting section 240 to the optical head 220 (see FIG. 12) of the first embodiment described above. Thus, the

10   following description will be focused on the configuration and operation involved with the wobble signal detecting section 240. The other configuration and operation are the same as those of the optical head 220 of the first embodiment and the description thereof will be omitted herein.

15   First, it will be described what signals pass where before a wobble signal is detected. In FIG. 21, the respective light quantity signals, detected by the light receiving section 207, are passed to the position signal detecting section 208 and TE signal generating section 209.

20   The position signal detecting section 208 detects the

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objective lens position signal, while the TE signal generating

section **209** detects the TE signal. Next, these two signals

are supplied to the offset correcting section **210** and

subjected to a predetermined computation using an offset

5   correction factor **k1**, thereby obtaining a corrected TE signal.

Following the notation of the first embodiment, the TE signal

is given by

$$TE = 6c - 6d - k1(6a + 6e - 6b - 6f) \tag{9}$$

The objective lens position signal and TE signal are also

10 passed from the position signal detecting section **208** and TE

signal generating section **9** to the wobble signal detecting

section. These two signals, introduced to the wobble signal

detecting section **240**, are subjected to a predetermined

computation using another correction coefficient **k2**, thereby

15 obtaining a wobble signal **WTE**. The address information and

other identification information are detected using this

wobble signal **WTE**. Following the notation of the first

embodiment again, the wobble signal **WTE** is given by

$$WTE = (6c - 6d) - k2(6a + 6e - 6b - 6f) \tag{10}$$

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In this case, the offset correction factor **k1** is defined

so as to minimize the offset of the TE signal waveform due to

the shift of the objective lens **204** by monitoring the waveform

of the TE signal generated when the beam spot crosses the

5   information tracks while no tracking control is being carried

out.   On the other hand, the offset correction factor **k2** is

defined so as to minimize the wobble signal offset variation

(i.e., an envelope variation at lower frequencies than the

wobble signal frequency) to be observed in the wobble signal

10   **WTE** while the tracking control is being carried out.

The features of the wobble signal **WTE** that has been

corrected with the objective lens position signal will be

described with reference to FIG. **7(b)**.   According to the graph

shown in FIG. **7(b)**, even if adjacent information tracks are

15   displaced by about ± 0.02 μm in the vicinity of the location

of -0.32 μ m, the three waveforms **117, 118** and **119** still

intersect each other at the origin and in the vicinity of the

location of +0.32 μm and no variation is observed in the TE

signal.   That is to say, the wobble signal **WTE** represented by

20   Equation (10) is unlikely to be affected by the displacements

of adjacent information tracks. The wobble signal of an adjacent information track represents the displacement of an information track that is adjacent to a given information track. Accordingly, if a wobble signal is unlikely to be

5 affected by the displacement, then the wobble signal should cause little crosstalk. Also, the crosstalk of the wobble signal appears as the offset variation of the wobble signal being monitored. Thus, to reduce the crosstalk, it is very effective to define the offset correction factor **k2** so as to

10 minimize the offset variation.

Thus, according to this embodiment, the crosstalk of the wobble signal can be reduced, and therefore, an address can be detected accurately enough even from a high-density optical disc with a narrow information track groove pitch.

15 The optical head of this embodiment is supposed to use the configuration of the optical head of the first embodiment. However, the present invention is in no way limited to this specific embodiment. Instead, this embodiment is also applicable to the optical head of the third, fourth or fifth

embodiment described above or even to the conventional optical head described above. Furthermore, this embodiment is applicable for use in any other optical head as long as the optical head has means for detecting the objective lens

5 position signal or light intensity distribution variation signal by splitting a given luminous flux to multiple surrounding areas along the information tracks.

In the foregoing description, the light transmitting and cut-off areas shown in FIG. 13, 16 or 18 are supposed to

10 belong to a diffraction element. Alternatively, those areas illustrated in any of these drawings may also be seen as illustrating light receiving areas and non-receiving areas of the light receiving section. This is because if there are light transmitting and cut-off areas in the diffraction

15 element, then the light receiving section should have associated light receiving areas and non-receiving areas. Accordingly, the light receiving function or non-receiving function (i.e., function of not using the light received) as described with reference to FIGs. 13, 16 and 18 may be

20 provided for respective areas of the light receiving section,

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not the diffraction element.

INDUSTRIAL APPLICABILITY

An optical head according to the present invention can reduce not only the deviation of a TE signal due to the tilt of a given optical disc but also an offset to be produced in the TE signal on the boundary between information tracks with different reflectances. Thus, an optical disc drive, including such an optical head, can perform a tracking control accurately enough on the information tracks of the given optical disc.